

# Compositions of Phobos and Deimos: The View from Visible to Near Infrared Spectroscopy



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# Phobos and Deimos: Targets of Interest for Robotic and Human Exploration

- Question of origin: Captured asteroid (*Burns, 1978*) or *in situ* (*Safronov et al., 1986; Craddock, 2011*)?
- No matter origin, exploring bodies reveal information about earliest time in solar system history
- Stepping stones for human mission to Mars

# Importance of Understanding Their Compositions

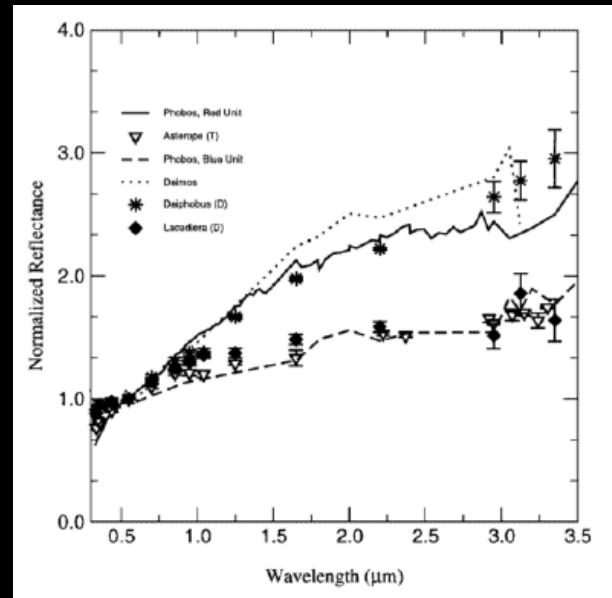
- Indicator of origin (Murchie et al., 2014):
  - **Captured primitive bodies**: compositions typical of material found in primitive meteorites
  - **Form from differentiated Mars (impact hypothesis)**: compositions with mafic minerals similar to basaltic Martian crust
  - **Form by late stage co-accretion with Mars**: compositions consistent with bulk Mars chondritic mafic mineralogy, e.g. ordinary chondrites
- Possibility for *in situ* resources for human exploration

# Composition: View in Mid-2000s

- VNIR spectral measurements showed Phobos had “blue” and “redder” material; Deimos looks like Phobos (e.g. Murchie & Erard, 1996)
- Redder material looked like D-type primitive asteroids
- No clear diagnostic evidence for mineral absorptions



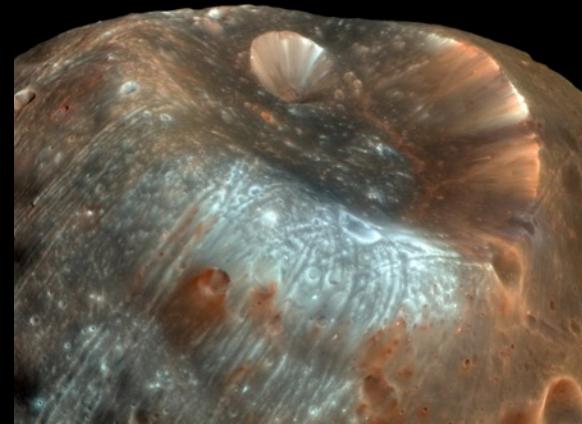
Murchie & Erard, 1996



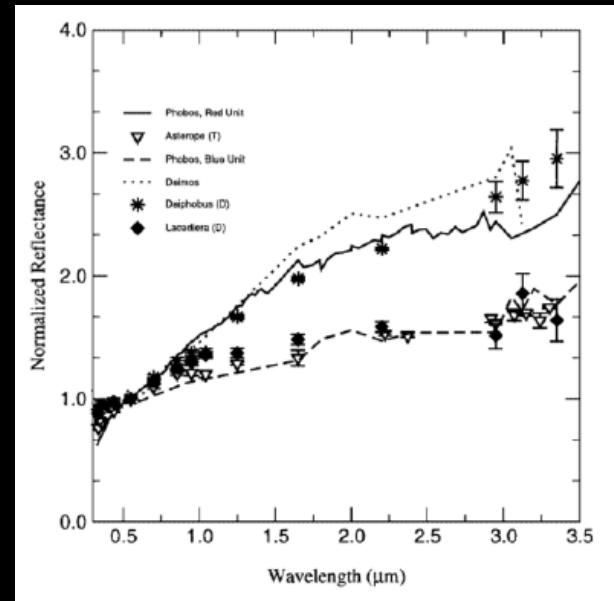
Rivkin et al., 2002

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Thomson et al., 2011



Rivkin et al., 2002

# CRISM Orbital Datasets

CRISM: High Spectral Resolution

Phobos



350 m/pixel

Deimos



1200 m/pixel

HiRISE: High Spatial Resolution Context

Stickney →



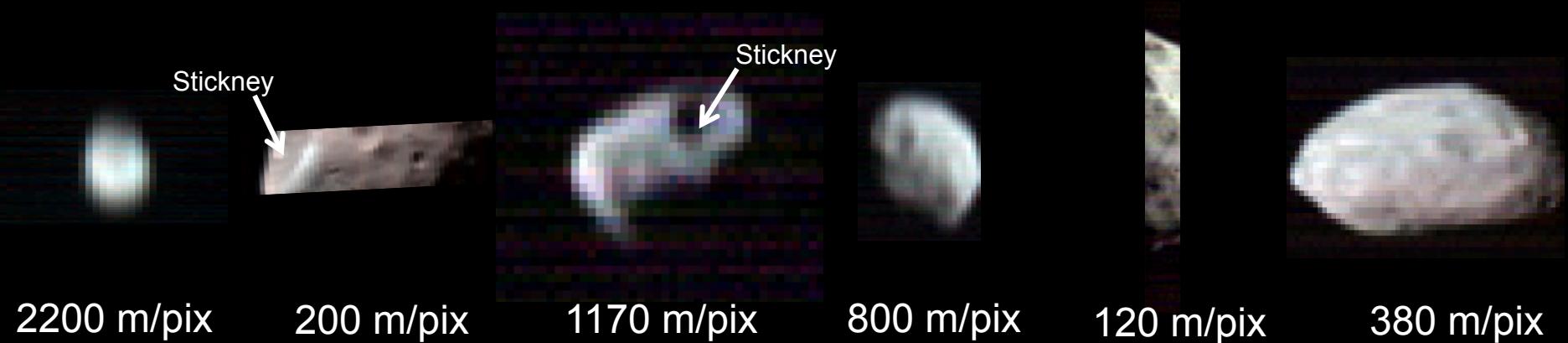
6.8 m/pixel



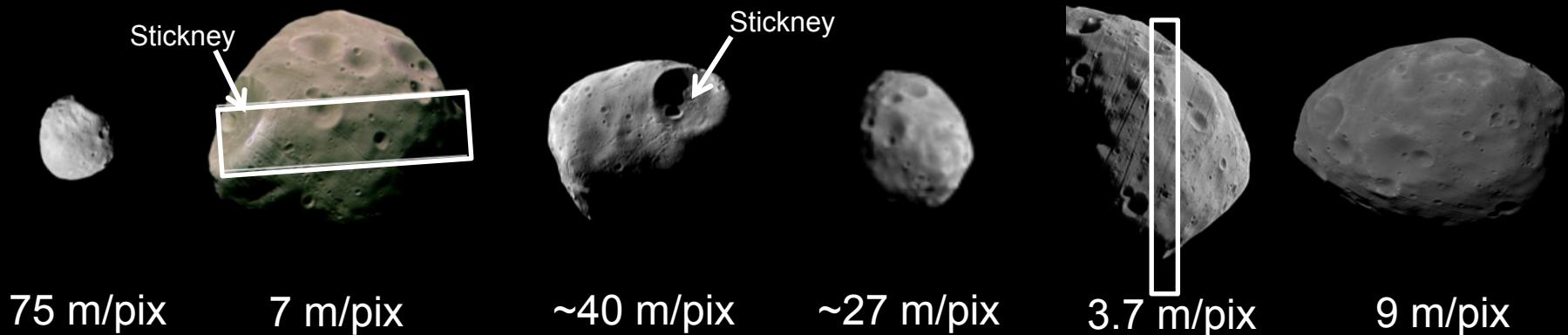
20 m/pixel

# OMEGA Orbital Datasets

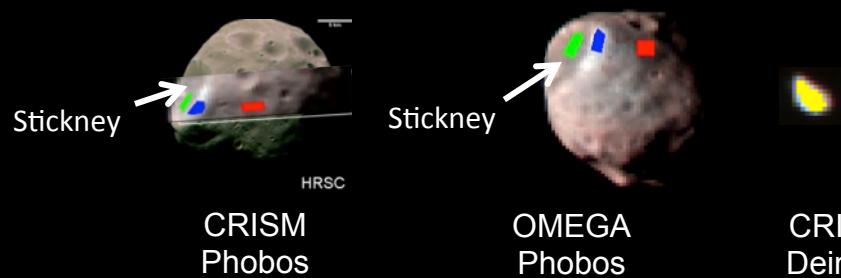
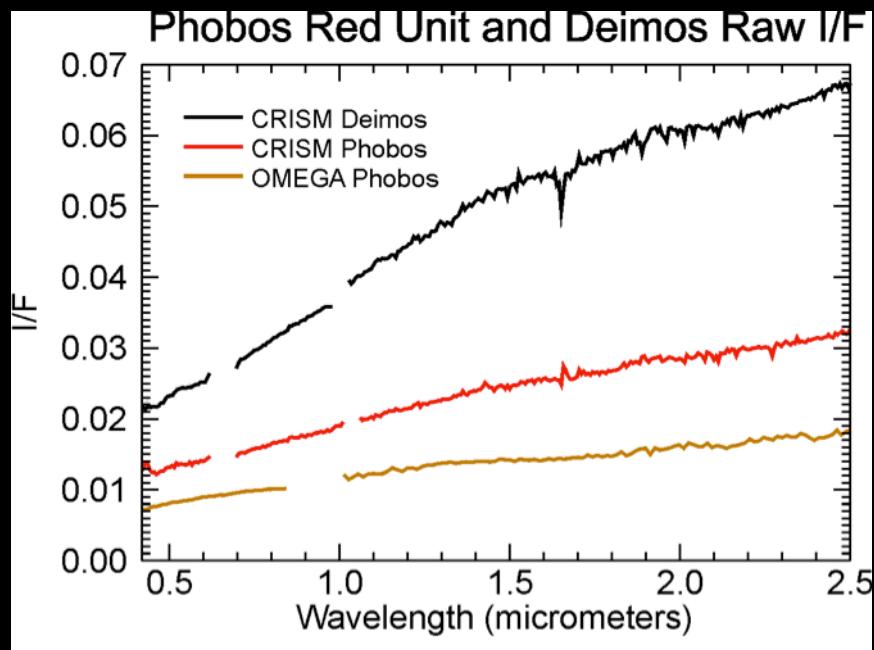
OMEGA: High Spectral Resolution



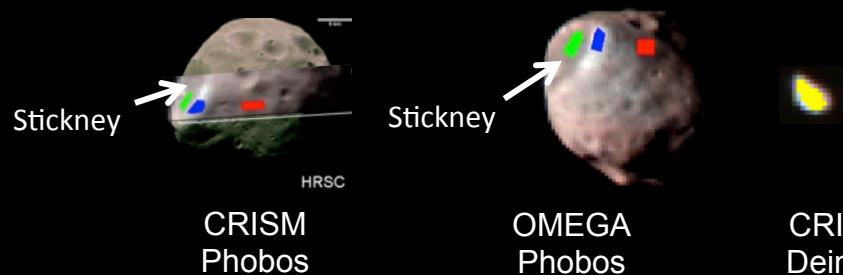
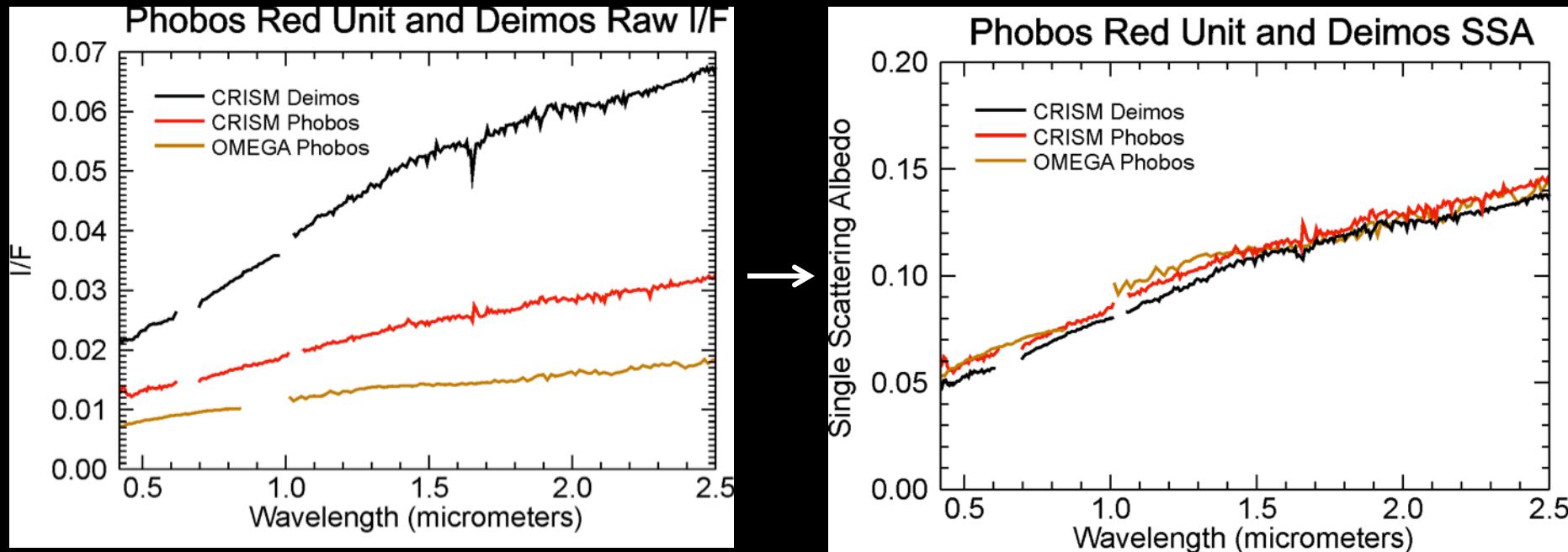
HRSC: High Spatial Resolution Context



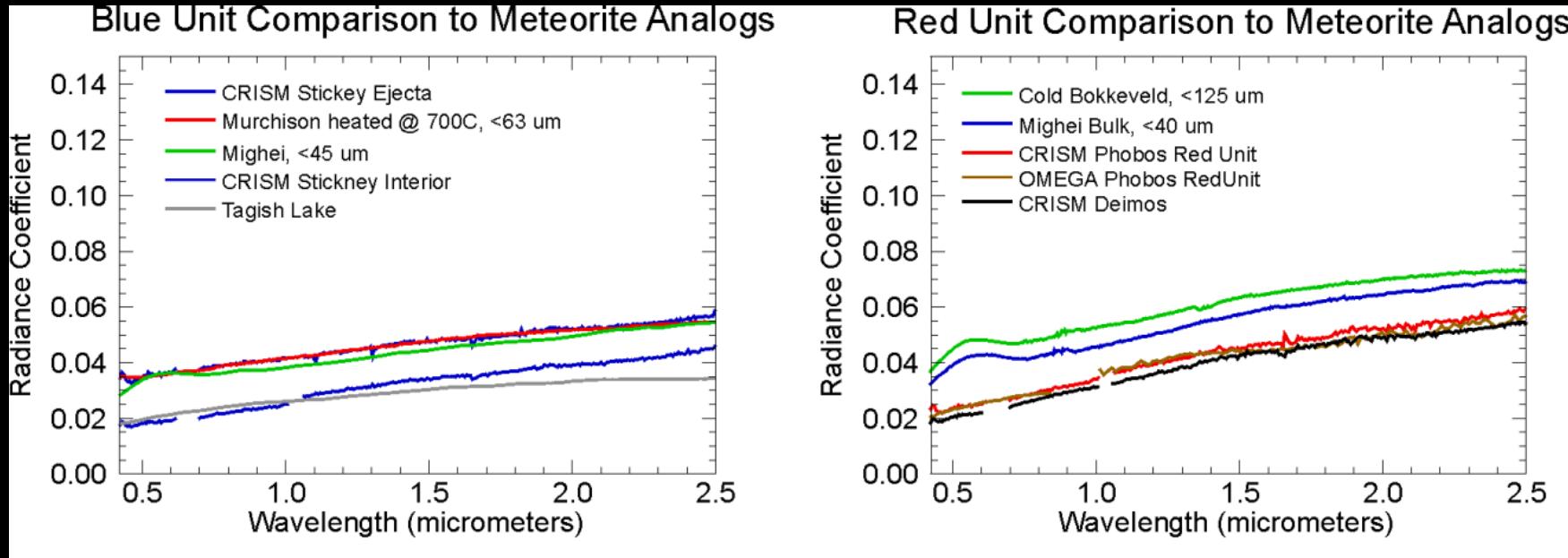
# Raw Spectra



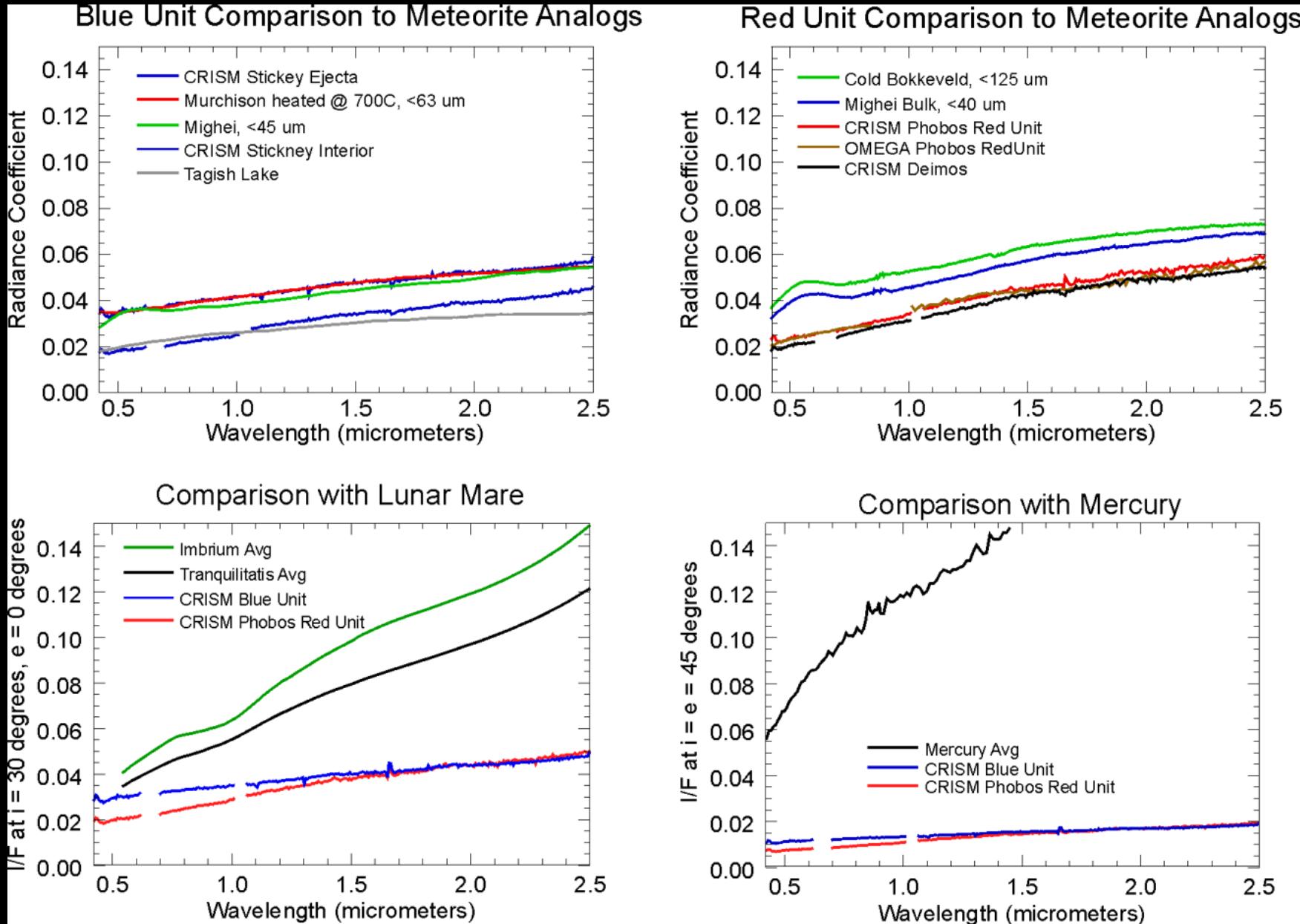
# Solve for Single Scattering Albedo at Every Pixel



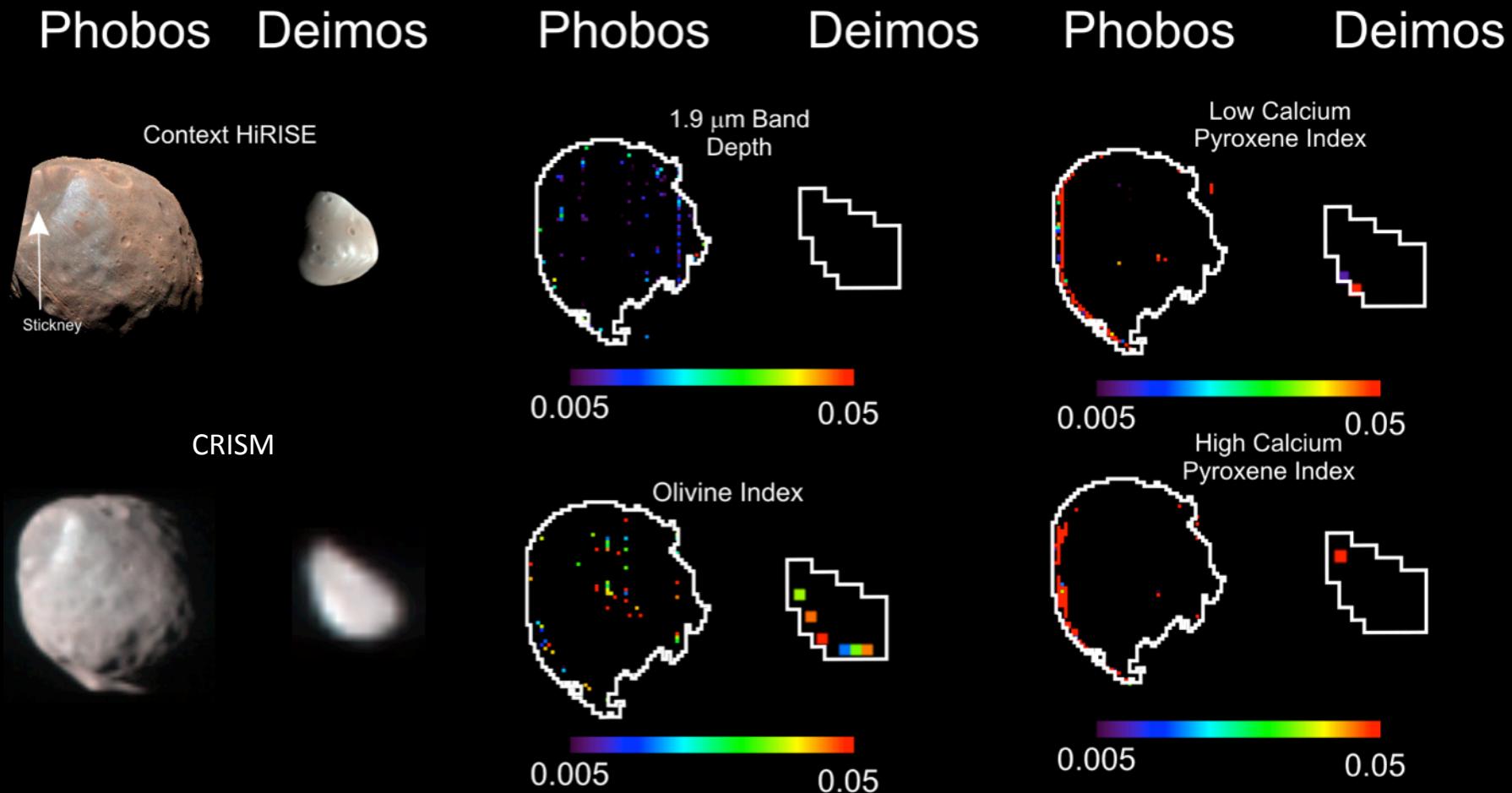
# Recast to Any Lighting



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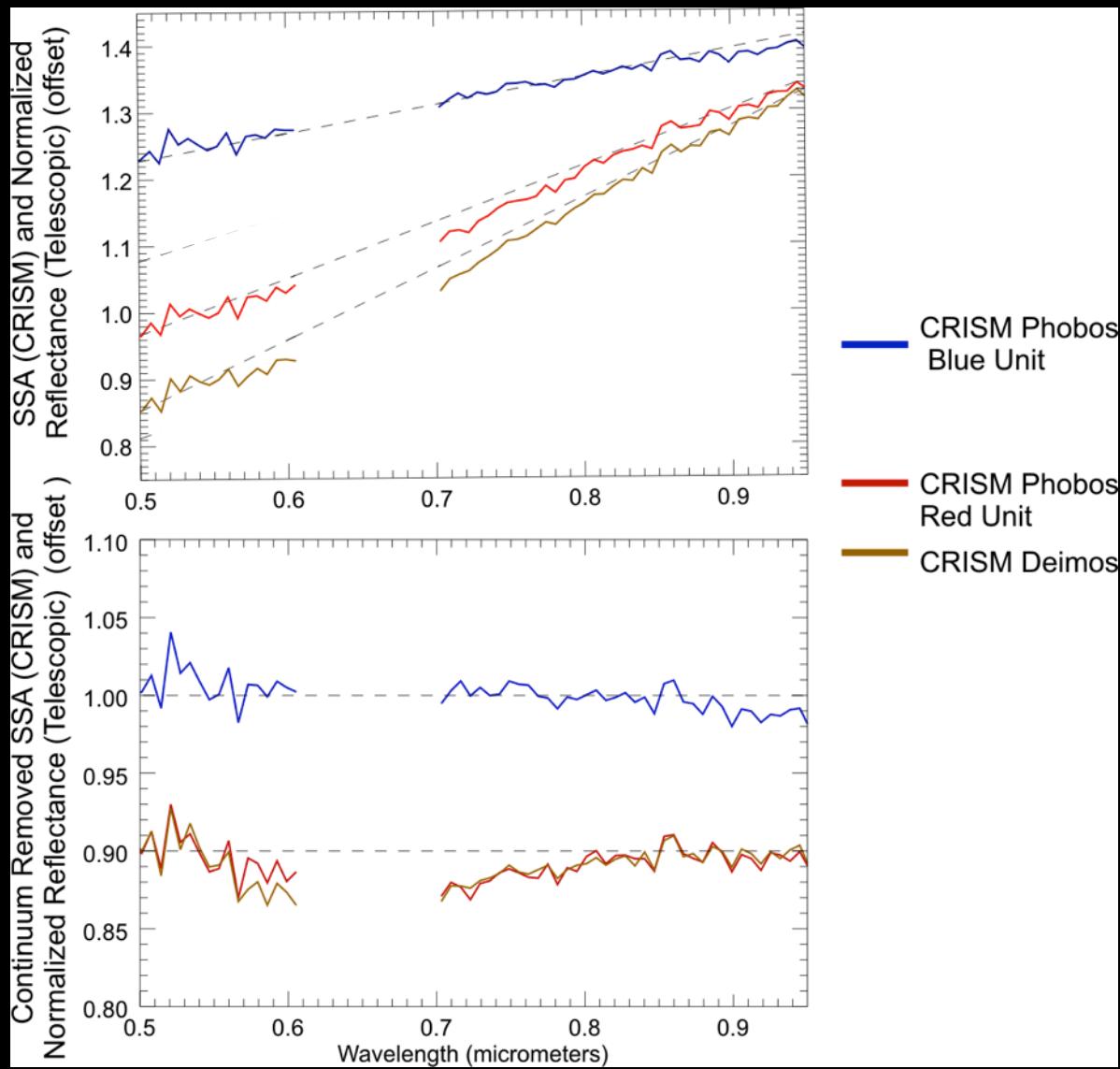
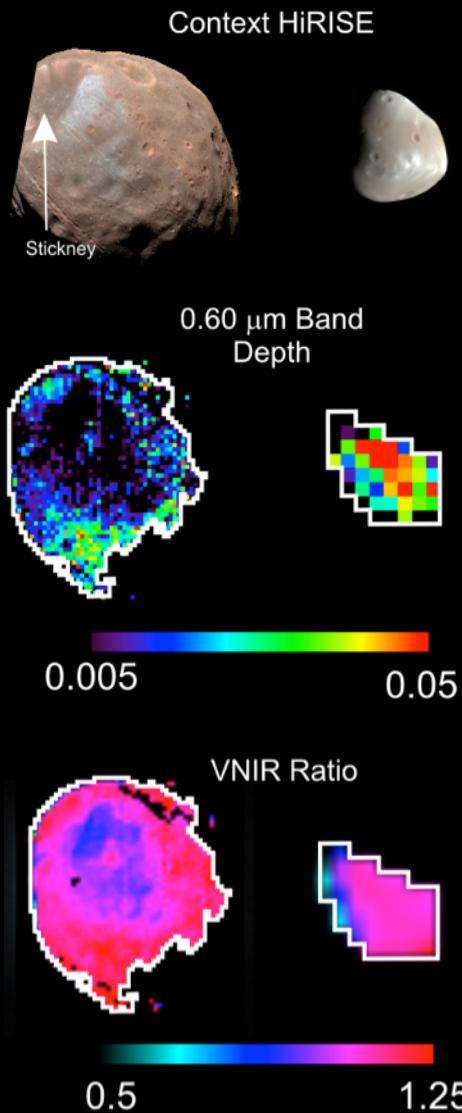


# Searching for Features in CRISM Data



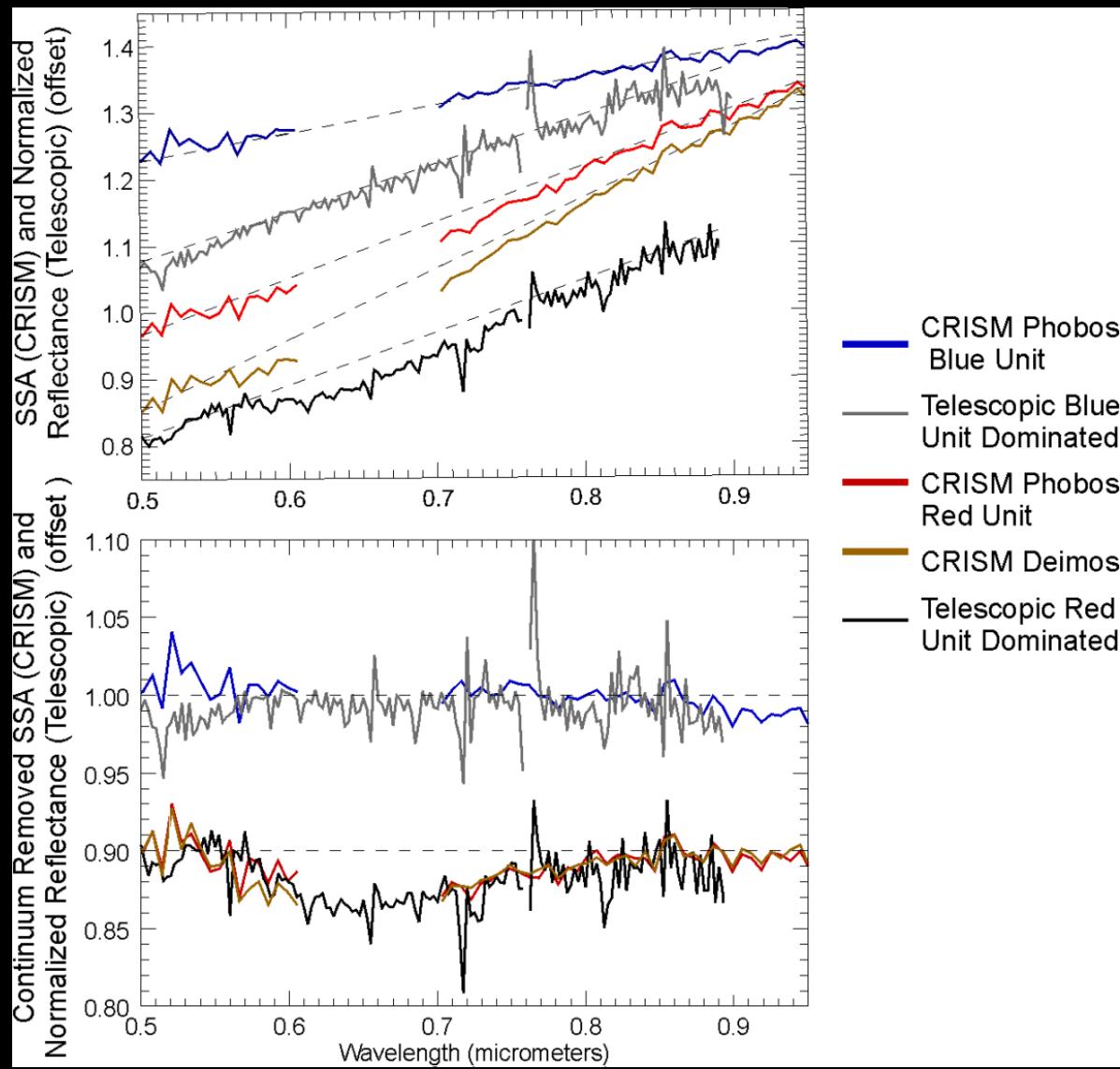
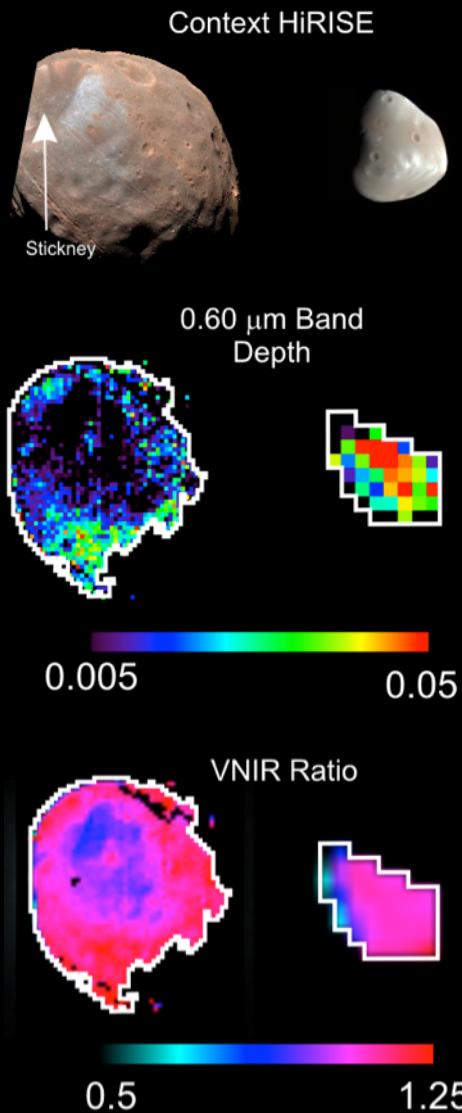
# Phobos Deimos

# Broad Feature at 0.65 $\mu\text{m}$

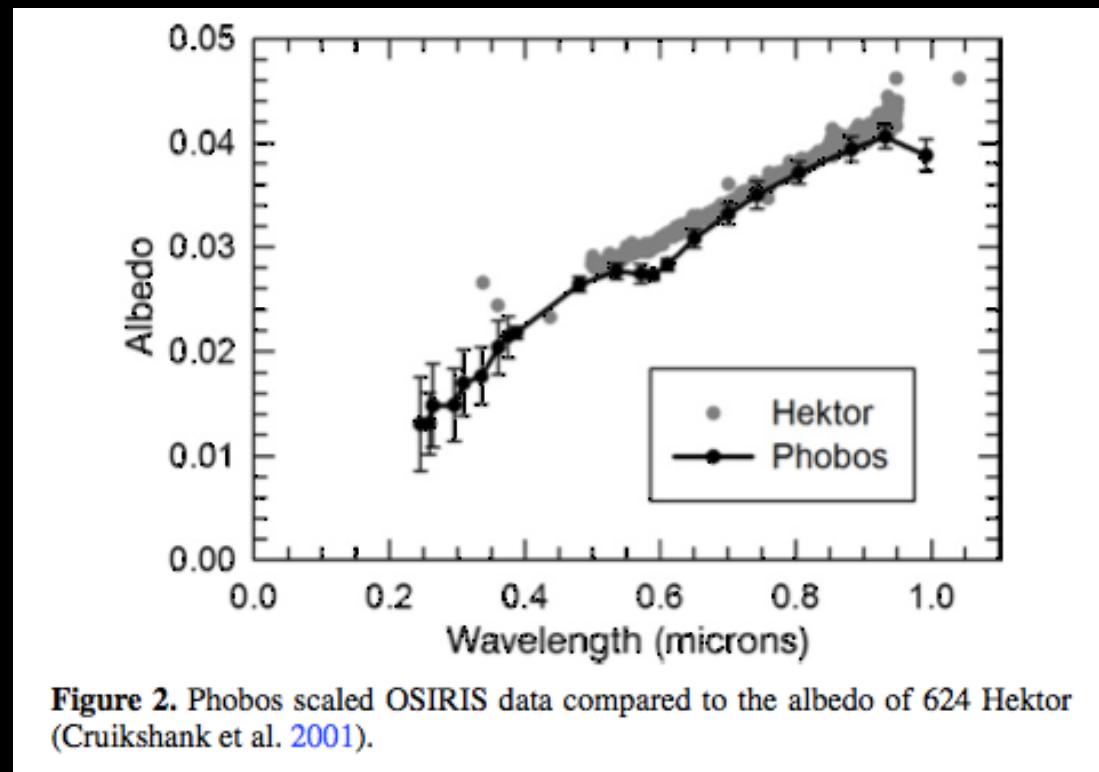
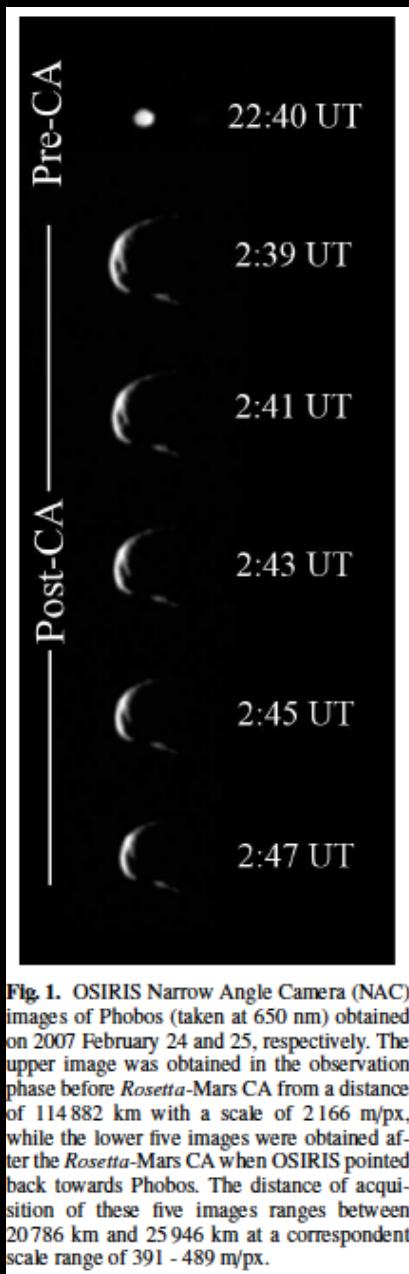


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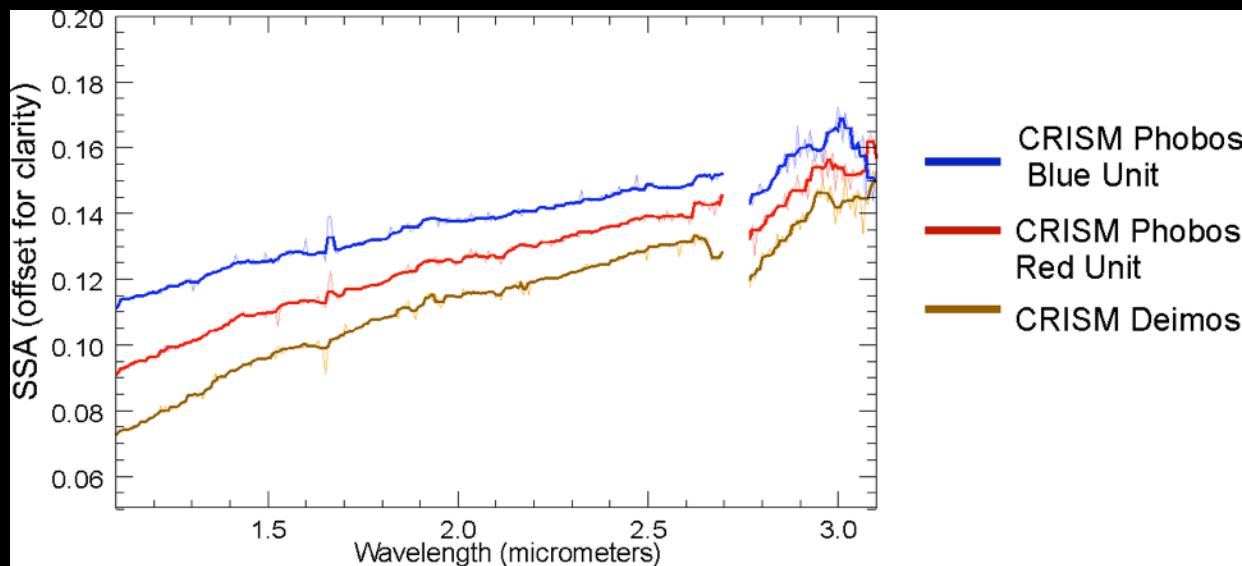
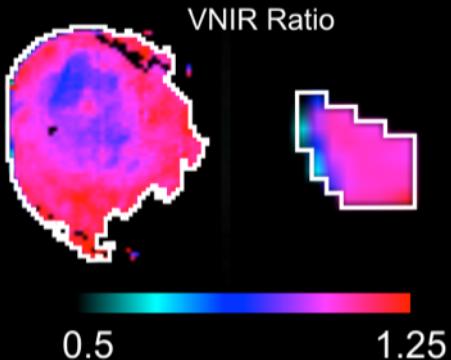
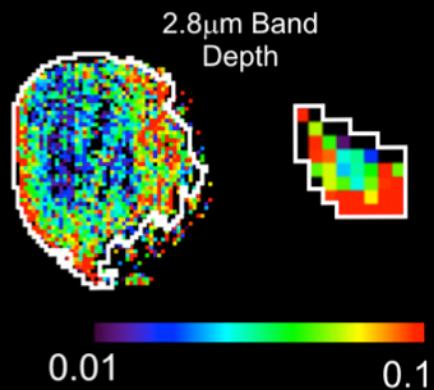
# 0.65 $\mu$ m Feature Visible in Rosetta Flyby Data Over Phobos Red Unit



Pajola et al., 2013

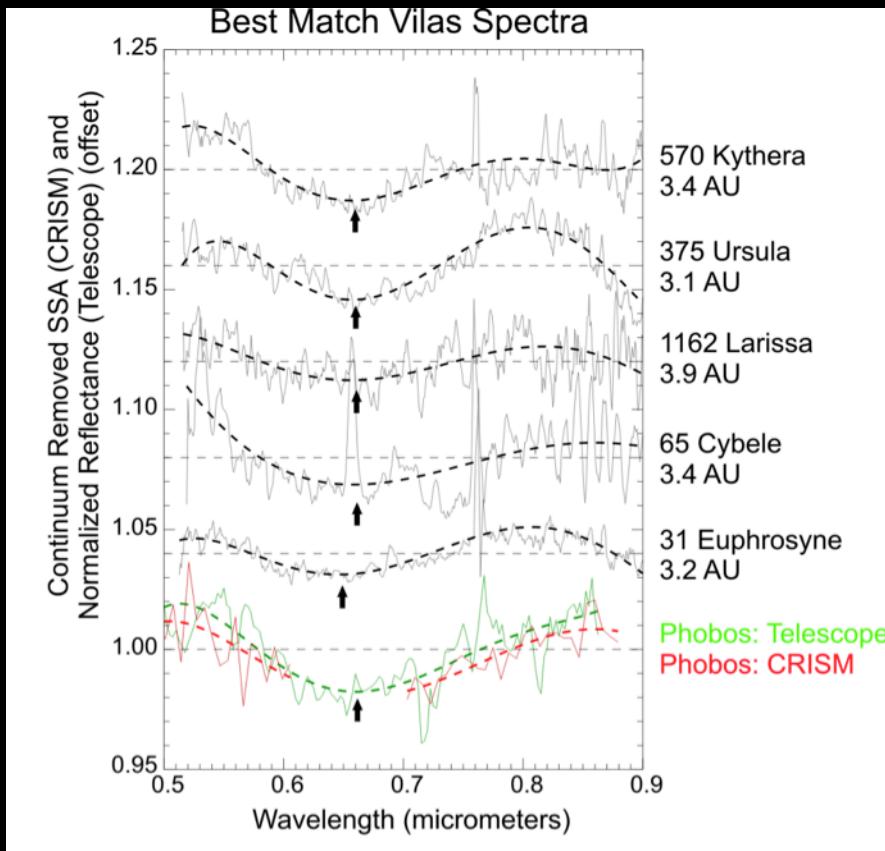
Phobos Deimos

# Feature at 2.8 $\mu\text{m}$



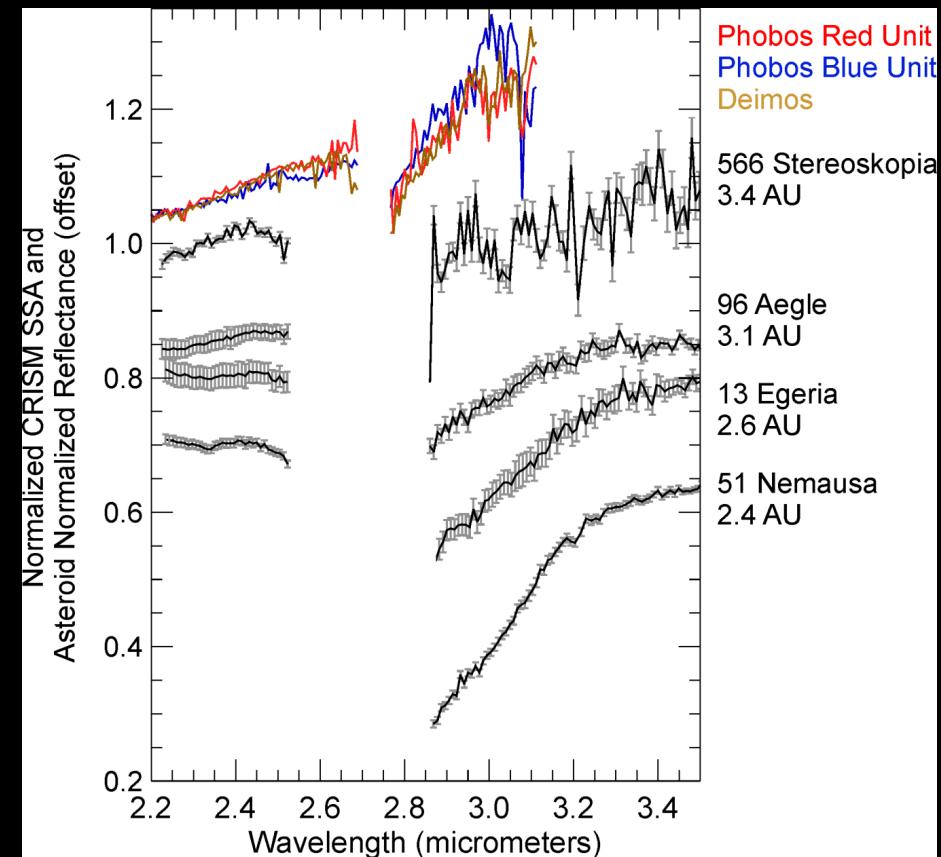
# Similarity to Low-Albedo Asteroids

## 0.65 $\mu\text{m}$ Feature



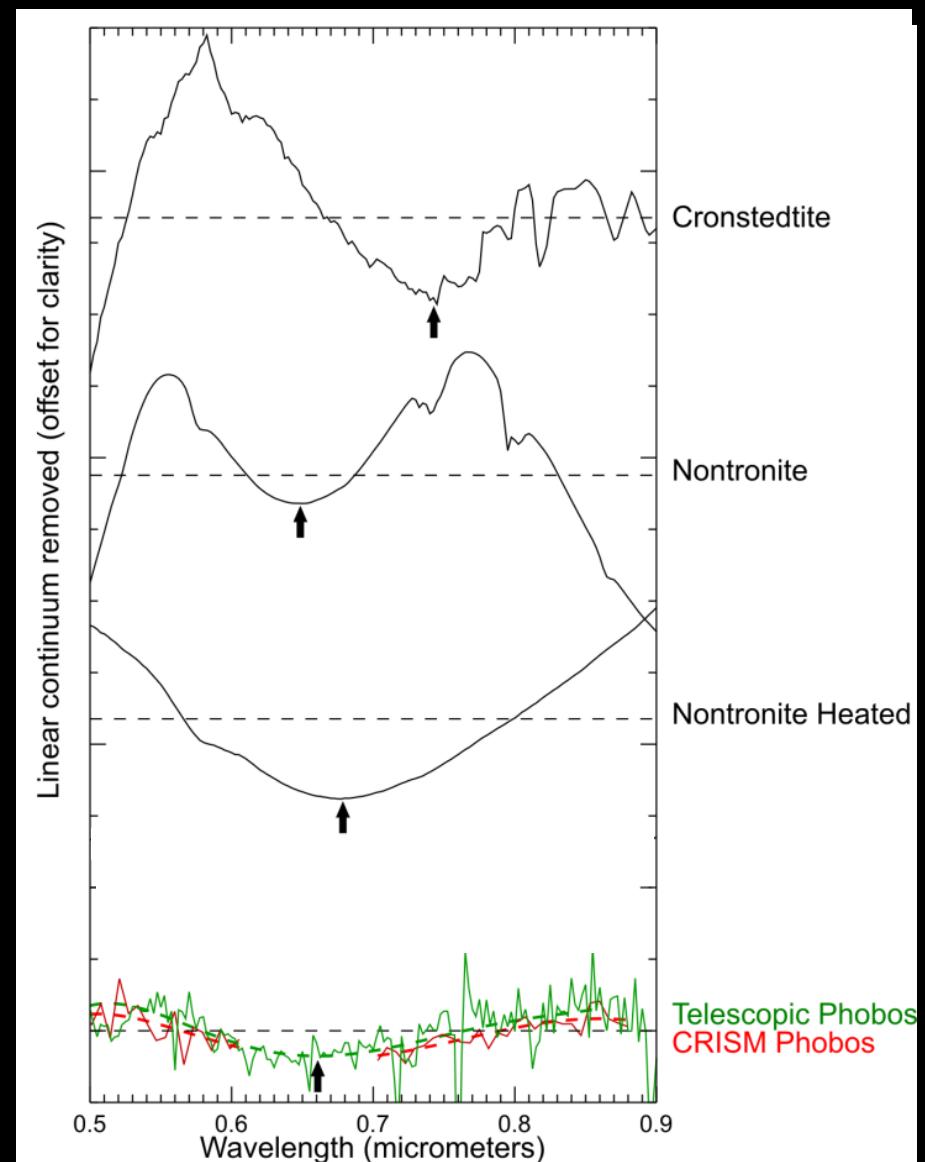
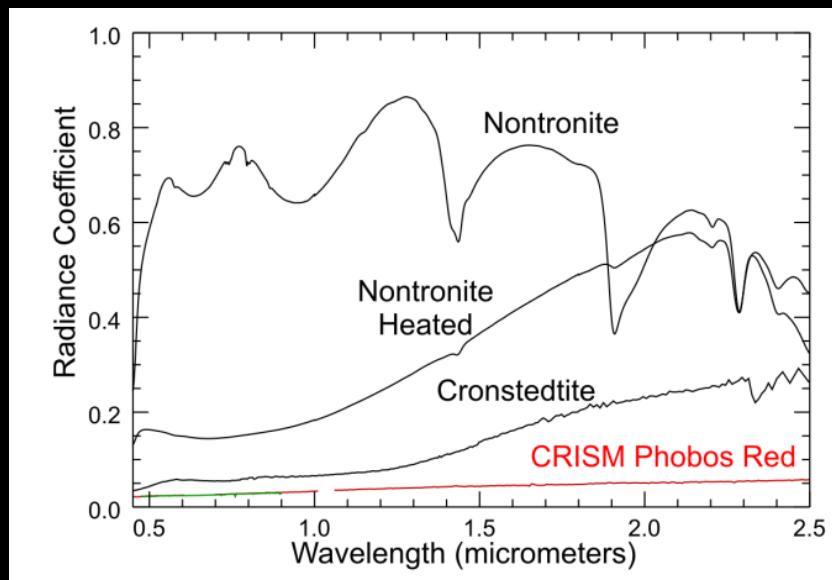
Comparison spectra from Vilas et al., 1998

## 2.8 $\mu\text{m}$ Feature

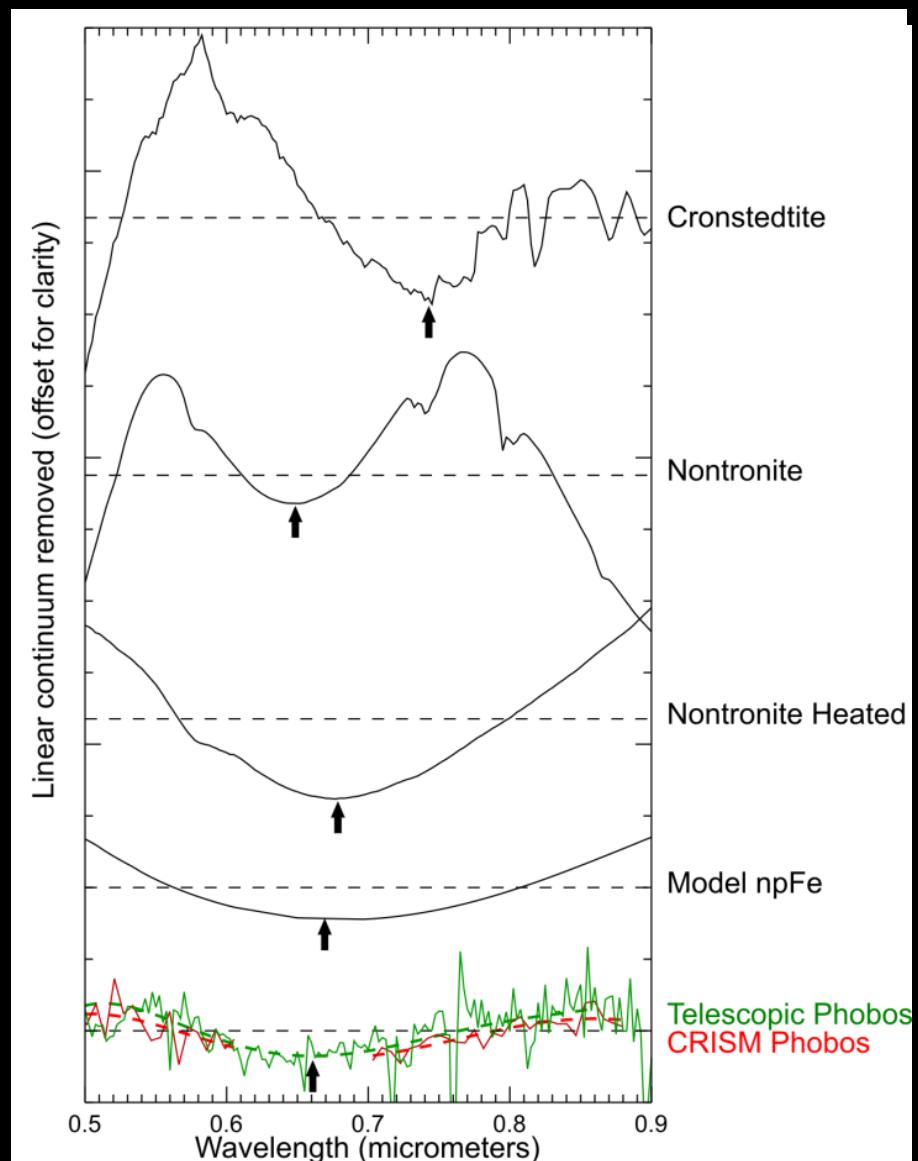
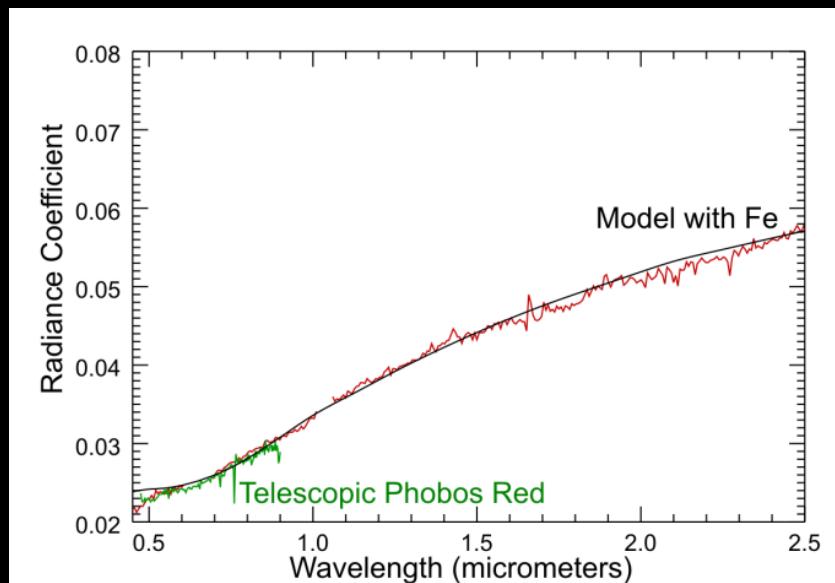


Comparison spectra from Rivkin et al., 1996; Rivkin et al., in prep

# Scenario 1: Phyllosilicate



# Scenario 2: Space Weathering



# Key Conclusions



- Phobos and Deimos are darker than even most space weathered materials
- Likely have carbonaceous chondrite-like compositions because they lack mafic absorptions and are spectrally similar to CM carbonaceous chondrites or Tagish Lake
- Pair of spectral features observed similar to those on low albedo asteroids
- To argue that moons formed *in situ* rather than by capture of primitive bodies requires carbonaceous materials to have been added to the Martian system during accretion or a late stage impact

# What's Next?



- Complementing VNIR spectra with UV and IR (see Glotch, Wed. afternoon talk) could help constrain possible compositions
- Questions about effects of space weathering and definitive chemical/mineralogical identifications likely only possible through *in situ* or sample return science (see several mission proposals in poster sessions)



# Range of OMEGA Lighting Geometries

